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ECONOMIC POTENTIALS OF IRRIGATION IN NORTH CAROLINA

Based on Soil Classification and Acreage Estimates from the National Inventory of Soil and Water Conservation Needs

UNITED STATES DEPARTMENT OF AGRICULTURE
Economic Research Service ● Resource Development Economics Division

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SUMMARY

The soils of the Coastal Plain and Piedmont of North Carolina were placed into three major irrigation classes according to likelihood of profitable irrigation. Procedures were also developed for adapting the general classification, based on all major crops for which the soil is suited, to a specialized classification for tobacco.

Basic soil data from the National Inventory of Soil and Water Conservation Needs were used to estimate the acres of cropland and pasture in each irrigation class. Estimates are given for the entire Coastal Plain, the entire Piedmont, the Neuse River Basin, and 83 individual counties within these regions.

The total area cropland and pastureland in the study area was estimated at 8,447,000 acres, of which 4,364,000 are in the Coastal Plain and 4,083,000 in the Piedmont. In the Coastal Plain, approximately 30 percent of the cropland and pasture fell in irrigation class 1, which has greatest likelihood of profitable irrigation; 50.5 percent was in irrigation class 2, and 19.5 percent in class 3. The distribution of cropland and pasture in the Piedmont was approximately 48 percent for irrigation class 1, 34.5 percent for class 2, and 16 percent for class 3. The remaining 1.5 percent was in mountain soils excluded from the classification.

Estimates for the specialized tobacco classification were limited to the first two irrigation classes. In the Coastal Plain, 43 percent of the cropland and pasture area was in class 1, and 2 percent in class 2. In the Piedmont, 37 percent of all cropland and pasture was in tobacco irrigation class 1, and 13 percent in class 2.

The Neuse River Basin, as defined by the North Carolina Inventory Committee, excludes the lower coastal portion and has a total land area of 2,871,000 acres. Estimates of acres of cropland and pasture for the first two irrigation classes were 539,000 acres for class 1, and 515,000 for class 2. The corresponding estimates for the tobacco classification were 659,000 acres for class 1 and 55,000 acres in class 2.

A systematic check for errors due to faulty tabulations indicated that errors are minor in large regions, though they may be considerable in a few individual counties. There were many errors in tobacco irrigation class 2 in the Coastal Plain, but this is a minor class.

An appraisal was made of the potential use of the irrigation classifications and estimation procedures given in this report. It was concluded that the classifications may help in estimating yield, water use, and costs of irrigation. Procedures given here for estimating acreages in various land classes will serve their most useful function if integrated with procedures for appraising in physical and economic terms the availability of water supply for those same areas.

ECONOMIC POTENTIALS OF IRRIGATION IN NORTH CAROLINA BASED ON SOIL CLASSIFICATION AND ACREAGE ESTIMATES FROM THE NATIONAL INVENTORY OF SOIL AND WATER CONSERVATION NEEDS

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INTRODUCTION

The general objective of this study is to provide information on irrigation potential in humid areas. The U.S. Soil Conservation Service recently completed a national inventory of conservation needs. Soil surveys were made of selected areas and used in making this inventory. A further objective of this study is to illustrate how these soils data may be used.

The following objectives were accomplished in this study of a pilot area in North Carolina: (1) Classification of soils into groups according to likelihood of profitable irrigation; and (2) estimation of the number of the acres of cropland and pasture for each irrigation class in the Coastal Plain, Piedmont, and Neuse River Basin areas of North Carolina and in the counties within these regions by using the National Inventory of Soil and Water Conservation Needs (hereinafter referred to as "Inventory").

The establishment of irrigation classes is described in section I. Section II describes how the Inventory sample of soil survey data was constructed and used for obtaining estimates. The presentation here is largely confined to single value or point estimates but an approximate method of confidence interval construction, developed by Howard L. Taylor, is given and more exact methods are briefly described. Potential uses of the irrigation classifications of estimating procedures, and of future research needs are evaluated in section III.

I. ESTABLISHMENT OF IRRIGATION CLASSES

This section gives a general account of the assumptions, procedures, and interpretation of the irrigation classification. The actual placement of soils by irrigation classes is given in appendix 1. Class 1 contains soils with the greatest likelihood of profitable irrigation, profitability in an absolute sense being undetermined. Soils in class 3 have little or no prospects of profitable irrigation under present or foreseeable economic conditions. Class 2 is an intermediate grouping of soils for which chances of profitable irrigation are less than in class 1 but higher than in class 3.

Assumptions and Procedures

Without knowledge of yield response, future cost-price relationships, farm organization, and management it is impossible to designate a soil as economically irrigable. However, even if such information is not available, it is possible to say that under most conditions, and for most crops, some soils are more likely to produce a profit from irrigation than others.

The basic assumption in setting up the classifications was that the soils most likely to return a profit from irrigation are the same soils that are considered the best in the region. Other soils may suffer more from lack of moisture, but in absolute terms income from irrigation is greatest on the best soils. A poor soil may be made fair or even good with irrigation, but net gains will probably be greater from making better soils even more productive with irrigation.

Some exceptions were made to the basic assumption that the best soils are the most profitable to irrigate. Even though they are rated poor to fair for most crops, the extensive Eustis and Lakeland Series were placed in the second highest irrigation class because they are well suited to peach production in the Sandhills. Most soils of the Coastal Plain that are productive but require drainage were placed in irrigation class 2. However, certain soils such as the Lenoir and Bladen Series were placed in irrigation class 3, even though they are capable of very good yields if drained, because these soils are difficult to drain and till.

Step 1. Placement of most favorable phase of each soil series

In the first step only one phase from each soil series was placed in one of the three irrigation classes. This was the least sloping and least eroded phase mapped. The other soil types and phases of each soil series were classified in the second step described below.

In line with the basic assumption, the primary criterion of classifying the low slope, least eroded phase of each soil series was general productivity. The major physical characteristics of each soil type classified in step 1 were tabulated and found helpful for certain subclassifications.

Step 1 was accomplished using North Carolina Technical Bulletin 115 by Lee (4). Heavy reliance was placed on tables 7 and 8 of that bulletin. These tables give the major physical characteristics of the more common soil types and rate them good to fair for each of the major crops grown. The remarks given in the tables concerning major hazards, such as susceptibility to drought and erosion, response to management, need for and feasibility of drainage, were also used as criteria in classifying for irrigation potential, particularly in borderline cases.

Irrigation classes 2 and 3 contained a wide range of soils. For the Coastal Plain, a subclassification was therefore established for these two classes based on uniformity of both physical characteristics and productivity rating. Soil conditions were found to be more complex and variable in the Piedmont, and a subclassification was not attempted there.

The extensive organic soils (peat and muck) in North Carolina were excluded from the irrigation classification because soil scientists concluded that not enough was known about these soils to permit their placement into an irrigation class. On the basis of present knowledge, these soils would seem to fit in irrigation class 3 and, if ever irrigated, are likely to require a complex system of drainage and water table management.

Step 2. Placement of other types and phases

A series of rules was next established for judging the effects of slope, erosion, texture variations, and flood hazards on irrigation profits. For example, slope class C (sloping or strongly sloping) and erosion class 2 (eroded or moderately eroded) were set as upper limits to irrigation class 1. Soils with higher slopes or more severe erosion could not be placed higher than class 2. Similarly, for gravelly, shallow, moderately gullied soils, and soils on low terraces, irrigation class 2 was the upper limit.

Step 3. Revisions and final placements

The preliminary classification was submitted to soil scientists of the Soil Conservation Service in North Carolina. They reviewed underlying assumptions and procedures and the placement of each soil type and phase.

Final listing of all soil series by irrigation classes is given in appendix 1. To facilitate evaluation and to provide a basis for further research on the economic potential of irrigation, the Coastal Plain subclassification of irrigation classes 2 and 3 was retained. As the listing applies to only those phases of each soil series that are most favorable for irrigation, the rules developed in step 2 for placement of less favorable series are also summarized in appendix 1.

Step 4. Classification of soils for tobacco

A list of soils rated "good" or "very good" for tobacco cultivation was prepared by irrigation classes and discussed with W. G. Woltz, Professor of Agronomy and tobacco specialist at North Carolina State University. The Alamance soil series rated "good to fair" for tobacco was also included in this list. The rules developed in step 2 for placing soils with certain surface textures in a lower irrigation class were found inapplicable to tobacco production on several leading soils. Two soil series (Enon and Creedmoor) were transferred from irrigation class 2 to class 1. The detailed modifications applicable for tobacco are given in appendix 1.

Interpretation

General

The irrigation classification places individual soil types and phases in three classes ranked by likelihood of profit from irrigation. Consideration is given to all crops to which the soils are suited. It has not been determined whether irrigation will actually produce a profit under prices, acreage allotments, landownership, management, and other conditions prevailing at any particular time. However, because of severe handicaps of soils in class 3, the chances of profitable irrigation for that class range from poor to zero.

Irrigation profits are determined by (1) yield increases obtained from various crops, (2) the prices received for such crops, (3) the cost of applying water, and (4) all other costs associated with producing crops under irrigation.

Reliable data are not available on changes in production and costs that are associated with irrigation nor are the prices that will prevail at any given time in the future known. Because of this lack of knowledge it is not possible to evaluate fully or with certainty all the factors influencing irrigation profits. This classification is based on judgment and considers only (1) the suitability of the soil for various crops, (2) the probable response to irrigation as indicated by soil productivity, and (3) the presence or absence of such limitations as poor drainage, high slope and shallow profile.

Variations in climate and in the cost of developing a water supply obviously influence irrigation profits but these variables cannot be incorporated in a soil classification since the same soil may be found under differing conditions of climate and water supply. These variables are therefore better considered apart from this soil classification. For example, Van Bavel and Verlinden have determined drought probabilities by regions for North Carolina (10).

Single-crop classification

In placing a soil in an irrigation class, the productivity of that soil for all major crops grown in the region was considered. If interest centers on only one specified crop, the classification needs to be modified to reflect likely irrigation response of soils to that crop. First, those soils unsuited to the crop in question should be excluded from the classification. Then, the placement of other soils may need to be modified but rarely will such an adjustment require a move up or down by more than one irrigation class.

Comparison of the same irrigation class in different regions

It is possible to apply the assumptions and procedures outlined above to any humid area where the general characteristics and productivity for various crops of the major soils are known. However, rules concerning the effect of slope, erosion, and similar variables on soil placement (step 2, p. 3) may need to be modified to allow for the peculiar characteristics within each region. Such variation may even be necessary for certain soils within a single region. For example, because the Caroline and Craven soil series are more susceptible to erosion, slope limitations are more severe for these soils than for others of the Coastal Plain. In the Piedmont, soils with a fine surface texture were placed in a less favored class than soils of the same series having medium or course surface textures. This was to allow for the effect of erosion on the texture of surface soil.

Further, since some regions are more productive than others, their irrigation classes, i.e., irrigation class 1, in the Piedmont and Coastal Plain are not likely to be comparable in prospects of profitable irrigation. Also, the variability within a given class may be greater for one region than another, as is the case with the North Carolina Piedmont and the more uniform Coastal Plain.

To make irrigation classes comparable over different regions would be considerably more difficult than ranking soils by classes within each region. It would require standardization of each class, possibly with the aid of benchmark or example soils for each class. On the other hand, a ranking of irrigation classes, regardless of location, may be more feasible.

Relationship between irrigation classes and land-capability classes

Land-capability classification is a grouping of soils primarily for agricultural purposes. This classification provides three major categories: (1) unit, (2) subclass, and (3) class.

The land-capability unit is a grouping of soils that is adapted to the same kinds of common cultivated crops and pasture plants and that require similar systems of management. The land-capability subclass is a grouping of land-capability units having similar kinds of limitations or hazards. The three limitations or hazards and their corresponding symbols in the Inventory for the Coastal Plain and Piedmont of North Carolina were: (1) erosion and runoff -e; (2) excess water -w; and (3) root zone limitations -s.

The third and broadest category in the land-capability classification places all the soils in eight land-capability classes. The risk of soil damage or limitations in use become progressively greater from class I to class VIII. Soils in the first four classes under good management are suited to cultivation as well as other uses such as pasture, woodland and wildlife. Soils in the last four capability classes are generally not suited to cultivation.

Irrigation class 1 is confined to land-capability classes I, II, and III. These first three capability classes also contain nearly 95 percent of cropland and pasture in the Coastal Plain falling in irrigation class 2, and almost 75 percent of such land in the Piedmont. The remainder of open land in irrigation class 2 is in capability class IV. Land in irrigation class 2 and capability class IV consists mostly of moderately steep phases of the best soils of the region. This is particularly true in the Piedmont. While such land is well suited to a number of crops it requires very careful management and conservation practices.

Since the Inventory provides estimates of acres in each land-capability class and subclass by major land uses the relationship between these categories and irrigation class 1 is given below:

Land-capability subclass and class	Percentage of cropland and pasture in irrigation class 1	
	Coastal Plain	Piedmont
I total	98	95
IIe	79	72
IIw	23	2
IIs	0	0
II total	32	66
IIIe	59	56
IIIw	0	0
IIIs	0	0
III total	7	48
IV, V, VI, VII, VIII	0	0

In the absence of other information, the percentage of irrigation class 1 for each land-capability subclass may be used as a rough guide for estimating the acres in other Coastal Plain and Piedmont areas best suited to irrigation. However, variations of physical conditions permitted within a subclass are wide, and for this reason the approximation suggested is recommended only for a general classification of land for irrigation, and for large areas since variations between soils included in the same capability subclass are more likely to offset each other over broader regions than in smaller areas such as individual counties.

II. ESTIMATING ACREAGES OF CROPLAND AND PASTURE BY IRRIGATION CLASSES THROUGH USE OF THE INVENTORY

This section explains how the Inventory sample was used to estimate acreage in the various irrigation classes. The findings for the Coastal Plain, Piedmont, and Neuse River Basin are given in this chapter. Estimates for individual counties in the Coastal Plain and Piedmont are summarized in appendix 2.

Full use was made of a comprehensive exposition by Howard L. Taylor of the design of the Inventory sample and its use in preparing estimates (9). Heavy reliance was also placed on chapter 8, "Stratified Random Sampling," in Sampling Techniques, by William G. Cochran (1).

The Inventory Sample

Background

The purpose of the Inventory as stated in a directive of the Secretary of Agriculture issued in April 1956, is to provide: "...reasonable estimates of the magnitude and urgency of the various conservation measures needed to

maintain and improve the country's productive capacity for all the people." Two national reports have been issued to date (2, 3). A third is in process covering the 50 States, Puerto Rico, and the Virgin Islands. These reports will be supplemented by individual State reports, of which 45 have been published as of May 1964.

As part of the Inventory, soil surveys were made of selected areas. The drawing of sample areas for soil survey and the processing of data was carried out by the Biometrics Unit of Cornell University and the Statistical Laboratories of Iowa State University and Texas A & M University. The sample for North Carolina was prepared by Iowa State University which also drew the Inventory sample for all States except for 11 in the Northeast region, and Virginia and West Virginia. Thus, while the sampling procedures described below apply specifically to North Carolina, similar designs were used in most of the Nation. There was some variation in area of sampling unit and sampling rate. This variation occurred mainly in the 13 Eastern States sampled by Cornell University, in irrigated areas and range country of the Western States, and in certain special situations.

Description of the North Carolina Inventory sample

The universe.--The sample survey was conducted on a county by county basis. The universe or area from which the sample was drawn includes the land area in each county and all water areas of less than 40 acres and all streams less than one-eighth of a mile wide. Federal land (except cropland) was excluded. Information on it comparable to the Inventory will be obtained separately through administering agencies.

The sampling scheme.--The Inventory sample is based on a geographic stratification. That is, each county was divided into subareas of equal size or strata, and individual sampling units were selected at random from each. The number of sampling units drawn from each stratum is proportional to the total number of sampling units contained therein. Further, since most of the strata were of equal size, the number of sampling units drawn from each was the same within a given county.

The strata.--The Inventory generally depended on the townships and sections of the rectangular survey for dividing counties into strata. Since North Carolina is not covered by the rectangular survey, a square grid of "townships" was superimposed on each county. These "townships" were further subdivided into 36 squares of 1 section (640 acres) each, as illustrated in figure 1, which shows the grid for Orange County, N.C.

The basic stratum from which the sampling units were selected consists of 2 tiers of 6 sections each, or 12 sections. Thus each "township" of 36 sections contains 3 strata.

The sampling unit.--The basic sampling unit is 1 quarter section (160 acres). Thus each stratum has 12 sections x 4, or 48 sampling units of 1 quarter section each.

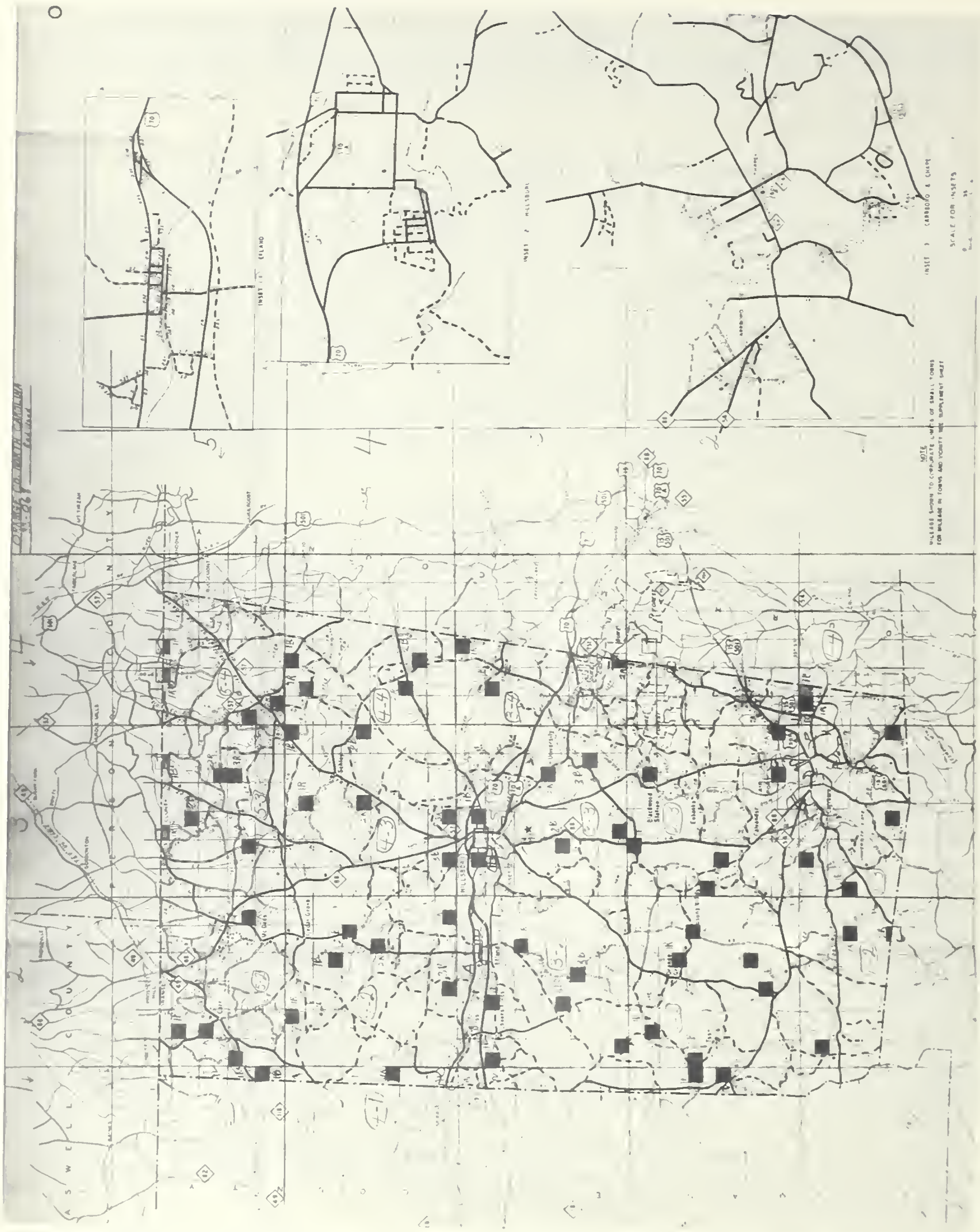

Figure 1.--Location of sample plots in Orange County, N.C.

Values observed.--For each sampling unit, delineations were made on maps of soil; slope; erosion; land-capability class, subclass, and unit; and major land use. The acreage of each combination of these variables was recorded on a tally sheet for each sample unit plot. The major land-use classes mapped were (1) cropland, (2) pasture, (3) forest and woodland, (4) other land (e.g., farmstead, idle, open country not used for agriculture, mines, and gravel pits), (5) urban and built-up areas, and (6) water and marsh areas.

The sampling rate.--The sampling rate varied with size of county. There were 4 different rates of sampling in North Carolina:

1. Four sampling units selected at random from each stratum, giving a sampling rate of 4 out of a total of 48 sampling units or a theoretical sampling rate of 4/48, or approximately 8 percent.

2. Two sampling units selected at random per stratum, giving a theoretical sampling rate of approximately 4 percent.

3. One sampling unit selected at random per stratum, giving a theoretical sampling rate of approximately 2 percent. This is the most frequent sampling rate employed in North Carolina and in many other States.

4. One sampling unit selected at random from each of two combined strata, giving a theoretical sampling rate of $\frac{1}{48x2}$, or approximately 1 percent.

Partial strata.--Since most counties are irregular in shape, superimposing the township and section grid on the county left numerous partial "townships" and partial strata (fig. 1). For some counties, elimination of publicly owned land from the area to be sampled also contributed to partial strata.

The method used for sampling partial strata was to select the units by drawing from a table of random numbers which covered all the 48 units of a complete stratum. Sampling units selected in this manner and contained in the partial stratum were included in the sample. If the sampling unit was not contained in the partial stratum, it was not included. This procedure resulted in selection of some sampling units of less than 160 acres, as some of the partial strata also contained partial sampling units (fig. 1).

Variation of actual sampling rates from theoretical rates.--Because of the method used, the expected sampling rate of partial strata is the same as the sampling rate of complete strata. However, in any one sample drawn, the actual sampling rate of the partial strata varies randomly about the expected theoretical rate. Thus the actual sampling rate for a county will generally deviate from the theoretical rate, particularly for counties with many partial strata. Sampling rates for most North Carolina counties did not deviate more than 10 percent from the theoretical rate. In a few exceptional counties, the deviation was as high as 20 to 33 percent.

Estimating Acres of Cropland and Pasture in Each Irrigation Class

Standard expansion method for counties

The standard method of estimating the total acres in a given irrigation class is simply to expand the sum of the observed sample values. The expansion factor is equal to the ratio of the area of the county from which the sample was drawn to the area actually sampled.

For example, the area of Wake County, N.C., from which the Inventory sample was drawn, is 553,200 acres, of which 5,795 acres were sampled. The expansion factor is 553,200 ÷ 5,795, or 95.462. Since the acreage of cropland and pasture in irrigation class 1 in the Inventory sample is 1,007, the total estimated acreage of open land of irrigation class 1 for Wake County is 1,007 x 95.462, or 96,130 acres.

An estimation of the number of acres in each of the general irrigation classes and tobacco irrigation classes 1 and 2 is given for 83 Piedmont and Coastal Plain counties in appendix 2, tables 5, 6, 7, and 8. These are based on standard expansion factors furnished by the Iowa State Statistical Laboratory for each county.

A check of errors due to faulty tabulations was made on 4 sampling units selected from each county, as described in appendix 3. Whenever the estimated measurement error of land misclassified under the general irrigation classes exceeded 2 percent of the total cropland and pasture area for the county, the county results were considered unreliable. For the tobacco classification, whenever the estimated acres misclassified in tobacco irrigation classes 1 and 2 exceeded 2 percent of the total estimated cropland and pasture area in those two tobacco classes, county results were considered unreliable. By these criteria, results for the general irrigation classification are unreliable for 14 counties and results for the tobacco classification are unreliable for 8 counties. Errors due to faulty observation were sizable for several counties but tended to offset each other over larger regions.

The standard expansion method is an approximation of the estimate that would have been obtained if the expansion from sample to total, or population values, had been done separately for each stratum and the results had been added for all strata into which the county was divided. The expected sampling rates and, therefore, the expected expansion factors for all strata are equal to each other and also equal to the standard county expansion factor. Therefore, the standard method of expansion for the entire county and the more laborious separate expansion within each stratum will yield similar estimates. The results obtained by the two methods of expansion from sample to population total will vary slightly because the actual sampling rates and expansion factors for partial strata will vary randomly about the expected rates. This slight discrepancy is accepted in the standard expansion method for the sake of the simplicity and ease of calculation offered by that method.

Counties not covered by the Inventory.--Four counties in the study area were excluded from the Inventory sample because a recently completed soil survey was available for them. For two of these, Duplin and Pasquotank Counties, the Inventory survey was approximated especially for this study by drawing the boundaries of the sample plots on the county soil maps. Sample plot boundaries were determined from photographic reproductions of county Inventory sample plot location maps. These maps were available for all North Carolina counties from the Iowa State University Statistical Laboratory. The acreage of cropland and pasture falling in each irrigation class on each plot was then measured.

For Anson and Yadkin Counties a complete tally of acres by soil type, slope, and erosion was available for cropland, pasture, woodland, and idle land. The total cropland and pasture area for Anson County given in the tally was some 18,000 acres greater than the corresponding area estimated by the Inventory Committee for North Carolina (5, p. 46). Therefore, when tabulating the acres of cropland and pasture falling in each irrigation class from the Anson County tally, the acreage of idle land in each irrigation class was also recorded. Then the acreage in cropland and pasture was reduced to the level adopted by the North Carolina Inventory Committee for 1958 (5, p. 46), by distributing the reduction among irrigation classes in the same proportion as the distribution of idle land among irrigation classes. This assumes that land that went out of farming between the time of the soil survey in Anson County and the Inventory was of the same type as the idle land found in Anson County at the time of the soil survey.

The complete tally for Yadkin County showed a total cropland and pasture area of about 3,500 acres less than the Inventory estimate adopted by North Carolina (5, p. 141). Accordingly, the estimates for Yadkin County used in this study were raised by approximately 3,500 acres, which were distributed among irrigation classes according to the distribution of total cropland and pasture derived from the tally.

Standard expansion method for county aggregations

County aggregation refers to a group of counties. Some, or possibly all, of the counties may be only partially included in the aggregation. Subsequent references to "counties in an aggregation" should be understood as counties or portions of counties included in an aggregation.

The total acres in a given irrigation class for an aggregation are estimated by the standard expansion method which is similar to the method used for counties. For each county, the sum of observed sample values is multiplied by the county expansion factor, as was calculated and explained above for Wake County. The results obtained are then added for each county falling within the aggregation to obtain the estimate of the population total for the aggregation.

For counties that are only partially included in an aggregation, estimates are obtained by multiplying the sample values for the portion inside the aggregation by the standard expansion factor available for the entire county.

The results are about the same as would be obtained by computing a separate expansion factor for the part falling inside the aggregation for each county that is partially included in the aggregation.

Table 1 demonstrates that the results of the two different methods of expansion differ only slightly. As an illustration, both methods were used to derive estimates of land in irrigation classes 1 and 2 in the Coastal Plain and Piedmont sections of 6 counties that have land in both regions. First, the sample values of acres by irrigation classes in each county were divided into Coastal Plain and Piedmont sections. For method a, the sample values for each county falling in the Coastal Plain and the Piedmont sections were each simply multiplied by the same county expansion factors. For method b, the area of each county falling in the Coastal Plain and the Piedmont was measured. Then separate expansion factors were developed for each region by dividing the Coastal Plain and Piedmont areas of each county by the section of the Inventory sample area for the county falling within each region. The sample values of acres in each irrigation class falling in Coastal Plain and Piedmont were then multiplied by their respective expansion factors.

Table 1.--Acres falling in 2 irrigation classes as estimated by 2 methods, sum of Coastal Plain and Piedmont sections of 6 counties 1/

Irrigation class	Coastal Plain			Piedmont		
	Method a 2/	Method b 3/	Method a / Method b	Method a 2/	Method b 3/	Method a / Method b
	Acres	Acres	Ratio	Acres	Acres	Ratio
General classification						
1	372,922	372,065	1.00	137,091	137,052	1.00
2	294,998	287,540	1.03	52,571	52,976	0.99
Tobacco classification						
1	507,582	502,680	1.01	149,854	150,511	1.00
2	39,794	38,715	1.03	21,584	21,151	1.02

1/ Harnett, Johnston, Lee, Nash, Wake, and Wilson Counties. Comparison was not feasible for other counties because measurement of area is complicated by presence of Federal land. Such measurement is required for method b.

2/ Only one expansion factor is computed for each county. This is done by dividing total county area from which sample was selected by the total sample area.

3/ Separate expansion factors are computed for Coastal Plain and Piedmont sections of each county by dividing the measured area of each section by the sample area falling within the same section.

For the sum of the 6 counties, differences in results obtained by the 2 methods did not differ by more than 3 percent. For individual counties, the differences are much larger; but even with as few as 6 counties, the effects of variations in the expansion factors in Coastal Plain and Piedmont from the expansion factor for the entire county tended to cancel.

The division of the sampling units between the Coastal Plain, Piedmont, and Mountain regions was easily accomplished by means of land resource areas (see p. 14) which are given for each sampling unit and which can be identified as belonging to one of the three physiographic regions. In the case of the Neuse River Basin, it was necessary to superimpose the drainage boundary of the basin on photographic reproductions of county sample plot location maps to determine which sample units fell in the Neuse Basin (8).

Table 2 summarizes the estimated acres in each of 3 irrigation classes, and in organic soils and mountain soils in the Coastal Plain and Piedmont areas of North Carolina. For the Neuse River Basin, only the first 2 irrigation classes were estimated; and basin boundaries were accepted as defined by the North Carolina Inventory Committee, which excludes the lower coastal sections of the drainage area (5, p. 162).

Table 2.--Distribution of cropland and pasture for selected regions of North Carolina

Region	Irrigation classes, general classification			Organic soils	Mountain soils	Total
	1	2	3			
	1,000 acres	1,000 acres	1,000 acres	1,000 acres	1,000 acres	1,000 acres
Coastal Plain	1,301	2,210	849	4	0	4,364
Piedmont	1,969	1,408	644	0	62	4,083
Neuse River Basin 1/	539	515	2/	2/	2/	2/

1/ Basin boundaries exclude Coastal Portion as defined by the North Carolina Inventory Committee.
2/ Not estimated.

It will be recalled that irrigation classes rank soils by likelihood of profitable irrigation and that irrigation class 3 contains soils with little or no prospects of profitable irrigation. Organic soils were not classified but are believed to fall in irrigation class 3. Mountain soils, found largely near the boundary of the mountain regions, were also excluded from the classification.

Land in irrigation classes 1 and 2 was estimated for the classification adapted to tobacco production; results for the 3 regions are given in table 3. As explained in appendix 3, a systematic check was made of errors due to faulty tabulations for irrigation classes. The estimated error component varied from 0.3 to 3.2 percent of the estimated totals shown in tables 2 and 3. One exception was tobacco irrigation class 2 in the Coastal Plain. The estimated error was estimated at 17.5 percent of the total acreage in this class. Estimates for this minor class are, therefore, considered unreliable.

Table 3.—Estimated acres of cropland and pasture falling in 2 tobacco irrigation classes for selected regions of North Carolina

Region	Irrigation classes, tobacco classification	
	1	2
	1,000 acres	1,000 acres
Coastal Plain	1,887	2/ 104
Piedmont	1,500	525
Neuse River Basin 1/	659	55

1/ Basin boundary excludes Coastal portion as defined by the North Carolina Inventory Committee.
2/ Unreliable because of an error component due to faulty observation of sample values in this study, estimated at 17.5 percent of the total.

Expansion from land-resource areas

A land-resource area (henceforth abbreviated as LRA) is a mapping designation, characterized by a particular pattern of soils. To the extent that the item being estimated is uniformly distributed within LRA's but varies between different ones, expansion from LRA's will result in more precise estimates (9, pp. 90, 91).

Expansion from LRA's is accomplished by an expansion factor computed by dividing the acreage of each LRA in a county, measured from a map, by the acres of the Inventory sampling units falling in the LRA (7). The observed sample values are expanded separately for each LRA and the results are added. Expansion factors for individual LRA's may vary by as much as 100 percent from the standard expansion factor for the entire county, due to the existence of many small and irregularly shaped LRA's.

In measuring the acreage of each LRA, it is necessary to exclude all areas such as Federal land that was excluded from the Inventory. Any LRA with no Inventory sampling units should be combined with another LRA having similar soil characteristics.

Several trials of the relative precision of expansion from LRA's and standard expansion were made for estimates of land in irrigation classes for counties and for the entire Neuse River Basin. Similar trials were previously conducted by Taylor for other variables (9, pp. 90-92). The precision of alternate estimates denotes the closeness with which alternate estimates approach the true population value as measured by the sample variances of alternative estimating procedures. Only approximate tests were feasible for comparing standard expansion and expansion from LRA's.

Both Taylor's studies and those conducted in this investigation lead to the conclusion that in most cases expansion from LRA's does not increase precision enough to warrant its use, and may occasionally lead to less precise estimates. This conclusion is reinforced by the much greater amount of computation required, compared to standard expansion, and the fact that in most trials the estimates resulting from the 2 methods differed by less than 5 percent.

Conceivably, in some cases, where the item under consideration occurs with uniform prevalence within LRA's but differs in prevalence between LRA's, considerable gains may be achieved by expansion from LRA's.

A note on confidence intervals

The estimating procedures given in this report are confined to single-value, or point estimates. For many purposes it is desirable to have estimates in the form of a confidence interval or a range for which a statement can be made concerning the probability of the actual population value being included in the range.

One approximate method of confidence interval construction is given here because of its ease of calculation and because it is not readily available in published form. This method was developed by Taylor and is therefore called Taylor's approximation (9, ch. 8).

A brief description of other methods evaluated for this study follows. All of them except method 3 have been previously described by Taylor (9, ch. 7). These methods include confidence interval construction using the following sample variances:

(1) Stratified variance based on the original geographic strata of the inventory. This method has only limited application because a minimum of 2 observations per stratum are needed to estimate within strata variances, while many counties have only 1 observation.

(2) Stratified variance based on a consolidation of the original strata by "townships." This method may be used when method 1 is not feasible because the original strata have only 1 observation. For a sampling rate of 2 percent, each "township" would be considered 1 stratum. For a 1 percent sampling rate 2 "townships" would need to be combined to form a stratum.

(3) Stratified variances based on strata formed by pairing adjacent sampling units. This method is an alternative to the preceding one in which "townships" are used as strata. It requires somewhat less work and will usually result in a narrower confidence interval.

(4) Random county variance ignoring the original classification. This method is an approximation requiring considerably less calculation than the previously described methods. The overestimate of the variance on which the sample is based is typically 10 to 15 percent. When dealing with large areas comprising many counties sampled at different rates, counties may be considered as strata and random county variances can be regarded as within strata variances. This approach avoids the rather tedious calculations required to compute and to weight within strata variances for numerous small strata.

(5) Stratified variances based on post-stratification by LRA's. This method is applicable when expansion by LRA's is used and requires a special estimating equation for post-stratified sample variances (9, p. 90).

Taylor's approximation

On the basis of trials in 3 counties and in the Neuse River Basin, Taylor's approximation emerged as satisfactory for a quick approximation in most situations. The only exceptions were when the item under consideration made up a very small percentage, say 1 or 2 percent, of the land area from which the sample was drawn.

The method does not require estimation of variance from sample data but is based on the following relationship, applicable with 160-acre sample plots, and derived for a number of counties in which "townships" were used to approximate the variance within geographic strata.

$$R.E. = \frac{0.413 \sqrt{1-\hat{R}}}{\sqrt{\hat{R}} \quad \sqrt{n}}$$

where:

$\hat{R}$ = the estimated prevalence rate of the item under consideration expressed as a fraction of the total universe area from which the sample was drawn.

n = the number of 160-acre Inventory sampling units.

R.E. = relative standard error of the sample mean.

The confidence interval can then be very conveniently developed as follows where the range is given as a percent of $\hat{Y}$, the total estimated acres:

$$\hat{Y} \pm t \quad (R.E. \times 100)$$

The "t" in the above equation is a standardized variate which takes on known values corresponding to various probability levels for each sample size. These values are available in published tables.

For example, if R.E. is 0.05, R.E. x 100 is 5 percent. For a large sample and a value of t = 1, a confidence interval of $\hat{Y} \pm 1 \times 5$, or 5 percent of $\hat{Y}$, will contain the true value of the item under consideration on an average of 2 out of 3 times. For a 95-percent confidence interval, t is approximately 1.96, and the corresponding range is 1.96 x 5 = 9.8 percent. That is, in 95 out of 100 cases, a range of 9.8 percent of the estimated total will include the true value.

The procedure is illustrated for irrigation class 1 in Wake County, N.C. The total area sampled was 5,795 acres of which 1,007 were found in irrigation class 1. The estimated total acres or "$\hat{Y}$" for irrigation class 1 are 96,130 acres (see standard expansion p. 10). The total number of 160-acre Inventory plots sampled, or "n", is 38.

$$R = 1{,}007 \div 5{,}795 = 0.1738, \quad 1\text{-}R = 0.8262$$

$$R.E. = \frac{0.413 \times \sqrt{0.8262}}{\sqrt{0.1738} \times \sqrt{38}}$$

R.E. is most conveniently derived by squaring both sides of the above equation.

$$(R.E.)^2 = \frac{(0.413)^2 \times 0.8262}{0.1738 \times 38} = 0.0213$$

$$R.E. = \sqrt{0.0213} = 0.1457, \quad R.E. \times 100 = 14.57 \text{ percent}$$

The confidence interval is:

$$96{,}130 \pm t \times 14.57 \text{ percent.}$$

For example, for a 95-percent confidence interval and a sample size n = 38, the "t" is 2.03. This is obtained from a table of "t" values for 37 "degrees of freedom." For Taylor's approximation the "degrees of freedom" are taken as n-1, in this case 37.

Thus, we can say for Wake County that for the type of sample that was drawn the true population value will be within a range of 14.507 x 2.03 = 29.58 percent of the estimated total in 95 out of 100 cases.

Table 4 gives the 95-percent confidence interval based on Taylor's approximation. The interval is expressed as a percentage of the total in each of the general and tobacco irrigation classes for which acreage estimates are given in tables 2 and 3. This range is largest for irrigation classes with the lowest prevalence rates.

Table 4.--Range of 95 percent confidence interval of cropland and pasture area falling in 3 general and 2 tobacco irrigation classes, selected regions of North Carolina

Region	Range of 95-percent confidence interval for irrigation class 1/				
	General classification			Tobacco classification	
	1	2	3	1	2
	Percent	Percent	Percent	Percent	Percent
Coastal Plain -----	5.8	4.3	7.3	4.7	21.1
Piedmont-----------	4.2	5.1	7.9	5.0	8.7
Neuse River Basin--	8.9	9.0	2/	7.7	30.0

1/ Based on Taylor's approximation. The range of the confidence interval is given in percent of the total acres for each class estimated in tables 2 and 3.

2/ Not estimated.

III. USE OF IRRIGATION CLASSES IN FUTURE RESEARCH

This final section is an appraisal of what uses can be made of the irrigation classification system and of the estimation procedures given in this report. This is accomplished by looking at 4 types of problems that are likely to arise concerning irrigation in humid areas in the decades ahead:

Problem 1. A farmer wonders if it would pay him to install an irrigation system on his farm.

Problem 2. A State agency reviews applications for permits to irrigate from a certain stream. If the permits are approved, streamflow during the critical season will be diminished to a level where other uses of water will need to be reduced.

Problem 3. For policy guidance, the U.S. Department of Agriculture makes one of its periodic appraisals of future national requirements of food and fiber and of the relative efficiency of meeting these requirements by alternative measures in various regions of the country.

Problem 4. A plan for river basin development is in progress. Future nonirrigation uses of water have been projected and their local and national benefits have been evaluated. Costs of reservoirs for various levels of stream regulation have also been determined. How much, if any, storage should be provided to allow for future irrigation development.

The information in this report does not answer these questions. However, it does make a logical start toward the research required to solve all 4 problems. This is illustrated by the following table heading:

Crop grown	Additional yield from irrigation	Cost of associated inputs excluding irrigation water
	Irrigation classes	Irrigation classes

This illustrative heading looks deceptively simple. For each crop it would first be necessary to determine which soils in each irrigation class are suited to that crop, and the irrigation classification of some soils might need to be changed as was illustrated for tobacco. Further, a subclassification such as the one developed for the Coastal Plain would be needed as variability within the major irrigation classes is too great for estimating irrigation yields and costs. To fill out this table for a single crop and a single soil would require a knowledge of (1) long-term rainfall records, (2) moisture-storage capacity of the soil, (3) rooting depth of the crop over the growing season, and (4) the relationship derived between crop-yield (possibly also quality) and soil moisture in combination with various levels of fertilization and possibly also other major input variables.

From this relationship the best combination of major inputs and yield increases associated with irrigation that is attainable by farmers would be selected. This combination would give the largest net returns based on expected cost price relationships. Cost of associated production inputs would cover all additional purchased inputs and value of extra labor associated with irrigation, except the cost and labor of applying irrigation water. An outstanding evaluation of this type for irrigation of tobacco and corn in North Carolina was made by Reutlinger and Seagraves (6).

One use of an irrigation classification is to help select key soils and key crops for such research. Since it is impossible to duplicate detailed research of the type suggested for all soils, it is necessary to select for investigation soils that are widely prevalent and that may be used for interpolation or other methods of making yield estimates for other soils. In this way the classification and estimation procedures presented here--or a more detailed and improved version--can provide the framework for systematic accumulation of knowledge.

The need for the type of data outlined in the preceding table heading is evident when one returns to the 4 types of humid area problems outlined. In the first problem, a farmer considering an irrigation system needs to know how much additional production he would obtain through irrigation, how much complementary inputs such as fertilizer and seed he would need to purchase, and what his added labor requirements would be.

He can then compare the added gross returns from irrigation with the additional cost of complementary inputs and harvest. An appraisal of capital outlay, annual operating costs, and labor required for an adequate irrigation system can be secured from an irrigation specialist. Such information is also provided by irrigation equipment dealers.

Having estimated all the costs of one or more irrigation plans the farmer can make a well-informed decision. It may also be possible to estimate, from long-term rainfall records in the region and the relationship between soil moisture and yield for the soils and crops under consideration, the degree to which fluctuations in annual crop production are reduced by irrigation.

The problem of approving irrigation permits is a very real one in a number of States. Estimates of additional production and inputs associated with irrigation could be obtained if the information indicated in the previous table heading were elaborated as follows:

Crop grown in the region	Added production per acre irrigated	Added gross returns less associated inputs per acre	Water requirement per acre in low flow period
	Irrigation classes	Irrigation classes	Irrigation classes

The State agency might require that a soil map of the area to be irrigated accompany each application and also a listing of the acreage of each crop to be irrigated in a typical year. The expected added production and gross return per acre foot of water could then be estimated.

Net returns to the farmer could also be approximated from a graph or table giving total annual per acre cost of irrigation as a function of total acres irrigated. With this information, the State agency could estimate the value to the farmer of critical water supplies used for irrigation. It would also have a basis for appraising the off-farm opportunities created by the additional production that would result from irrigation.

If the procedure just outlined is too cumbersome, an alternative approach would be to make a survey of representative farms that are now irrigating in the critical water supply area. Using the basic information of additional yields and inputs associated with irrigation, typical economic returns per acre foot of critical water supply used up could be estimated. The results might be adjusted to reflect anticipated changes in prices and production practices. If there are no farms that are now irrigating, the same information might be obtained by budget or linear programing techniques.

To continue with the examination of anticipated humid area irrigation problems, consider the example in which the U.S. Department of Agriculture periodically estimates the relative efficiency of meeting future requirements

through irrigation in a humid region. What is needed is an estimate of the cost per unit of additional output for the crops under examination and of the potential quantity of production.

The additional output and associated production costs (other than direct irrigation costs) could be derived from the information outlined in the first illustrative table heading. The acreage base to which the estimates apply can be estimated through the Inventory as was done in this study. If interest centers on specific crops, the estimates of acreage base could be refined considerably by adapting the classification to the specific crop and eliminating all soils not suited to that crop, as was illustrated for tobacco.

To complete the cost estimates, typical irrigation costs would need to be derived. As in the previous example, typical per acre costs of small, medium, and large irrigation systems could be derived and weighted according to the proportion of their expected prevalence.

If irrigation costs vary widely, the region could be divided into several subregions in which the water supply situation is similar. Similarly, the natural distribution of land classes over potentially irrigable fields may make it unrealistic to assume that it is possible to irrigate land in irrigation class 1 without also irrigating some land in the lower irrigation classes. In such cases soil maps may be used to divide the region into 3 parts, each containing a large number of segments with soils primarily in irrigation classes 1, 2, and 3, respectively. The acreage in each of the 3 irrigation classes would then be estimated from the Inventory sample separately for each of the 3 parts. The cost per unit of added output of production would then be computed for each part by weighting the values of irrigation classes 1, 2, and 3 according to their prevalence.

The most difficult of the 4 humid area irrigation problems discussed here is that of the river basin planning group. This group needs to decide how much, if any, storage for irrigation to incorporate into the river basin development plan. They must estimate:

1. The extent of future irrigation development that would draw from various stream reaches if water were available.

2. The amount by which water supply would be lowered in the low-flow seasons and the corresponding upstream storage requirement.

3. The comparative costs of upstream storage and local storage on farms.

4. The local and national benefits that would result from future irrigation. For crops such as tobacco, produced under acreage controls, the difference between local and national benefits needs to be recognized.

Perhaps the most difficult of these is forecasting the extent of future irrigation. This is of course related to local benefits of irrigation, particularly on the farm.

The usual procedure has been to project expected future irrigation from past trends, taking into consideration the upper limit on acreage of irrigable land, water supplies, returns from irrigation, and institutional factors to appraise future growth rates. While it is beyond the scope of this statement to discuss in detail the irrigation phase of river basin planning, the value of the type of research suggested here can be demonstrated.

Starting again with the first illustrative table, which is derived from a previously determined price level, the planners could compute added production, gross returns less associated costs, and water requirements per acre. Irrigation cost could be estimated as previously suggested to derive net returns per acre. From the same basic information the returns to farmers on the investment required for irrigation could also be estimated. Through an appraisal of capital availability and alternative investment opportunities open to farmers, it may be judged that a minimum return on capital outlay is required before farmers would invest in irrigation.

With this information, future trends in irrigation can be appraised more realistically. In particular, the upper limit on future irrigation development may be set at a more realistic level. For example, it may turn out that irrigation may not offer a sufficient return on investment for irrigation class 2, except for such high-value crops as tobacco. However, tobacco is more likely to be grown and irrigated on land falling within class 1. With a knowledge of what crops could be profitably grown and the maximum acreage base for each crop, future irrigation trends can be more realistically projected.

The same basic information may also be used to derive an irrigation benefit function which shows the amount of local and national benefits derived with each successive increment of irrigation development. This function would help the planners decide how much irrigation to provide for.

Construction of such an irrigation benefit function would involve an assumption of the order of irrigation development--what land and what crops would be irrigated first. For example, it may be logical to assume that the combination of soils and crops producing the largest local benefits would be irrigated first. It is recognized that the actual pattern of future irrigation development may differ and that in fact, the most economic level of storage for irrigation cannot be foretold. The point is that planners are required to appraise the extent and benefit of future irrigation, and that such appraisals will be closer to the future course of events if they are based on the research suggested here.

In summary, the examination of problems related to humid area irrigation suggests that a classification of land by irrigation classes and the procedures for estimating the acreage in each class can serve a useful function, if this classification is usable for deriving yield estimates and economic returns under given conditions. It is, therefore, hoped that the classification presented here will be examined for this purpose, improved, adapted where needed, and used as a framework for the orderly accumulation of knowledge of economic return from irrigation.

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APPENDIX 1. GUIDE TO SOIL PLACEMENT BY IRRIGATION CLASSES

The listing of soil series by irrigation classes and Coastal Plain subclasses (pp. 26-28) applies only to the most favorable phases for irrigation that are mapped for each series. In the acreage tabulations less favorable phases of soil series listed under irrigation classes 1 and 2 were placed in a lower irrigation class according to the rules given in this appendix. The soil listings by irrigation classes apply to the general classification which is based on all major crops grown in the region. Procedures used for developing a specialized classification for tobacco are described below.

Effects of Variation Within Soil Series on Placement in Irrigation Classes

All types and phases of a soil series fall in the same irrigation class except for the following conditions.

Slope and erosion

Slope class D (moderately steep).--All soils in irrigation class 1 are placed in class 2.

Slope classes E and F (steep, very steep).--All soils are placed in irrigation class 3.

Erosion class 3 (severely eroded).--All soils in irrigation class 1 are placed in irrigation class 2 if slope is less than "D" slope. If slope is D all soils are placed in irrigation class 3.

Erosion class 4 (rough and gullied land).--All soils are placed in irrigation class 3.

Special limitation for subclass 2b, Coastal Plain.--These soils (principally the Eustis and Lakeland series) are shifted from irrigation class 2 to class 3 beginning with D slopes rather than E slopes.

Special limitation for subclass 2c, Coastal Plain.--The soils (principally the Caroline, Craven, and Wahee series) are shifted from irrigation class 2 to class 3 for slope class B with erosion class 3 and for all C and D slopes, regardless of erosion class.

Other soil conditions

Gravelly, slaty, shaly, shallow, moderately gullied, subject to occasional flooding, soils on low terraces.--All soils in irrigation class 1 are placed in class 2.

Stony.--All soils in irrigation classes 1 and 2 are placed in the next lower class.

Very shallow.--All soils are placed in irrigation class 3.

Land capability VII and VIII (generally unsuited to agriculture except possibly forage and tree crops).--All soils are placed in irrigation class 3. (Note: Because of other limitations all soils in class VI also fell in irrigation class 3, while irrigation class 1 was found only in capability classes I-III.)

Texture of surface soil

Piedmont.--For a soil series in irrigation classes 1 and 2, all soil types with clay loam, sandy--or silty clay loam, and clay surface textures are placed in the next lower irrigation class if the same soil series is also mapped as a sand, loamy sand, sandy loam, or silt loam. Helena and Durham sandy loam, thick surface phase, are placed in irrigation class 2 subject to the same slope and erosion restrictions that apply to the thick surface phases of irrigation class 1, Coastal Plain that follows.

Coastal Plain.--All soils in irrigation class 1 with sand, fine sand, and thick surface phase are placed in irrigation class 2. Thick surface phases are subject to the special slope and erosion restrictions that apply to irrigation subclass 2c, Coastal Plain.

Irrigation Classification for Tobacco

Only soils rated by Lee as "good" or "very good" for tobacco were included in the tobacco classification (among them, the Alamance soil series, rated "good to fair"). The following changes were made in soil placement.

Piedmont.--Enon and Creedmoor soils were shifted from irrigation class 2 to irrigation class 1. For A and B slopes on the Appling, Cecil, Durham, and Granville soil series, the already mentioned limitations due to texture of surface soil and erosion class 3 do not apply. The limitations on thick surface phases of Durham do not apply except that the thick surface phase is shifted from irrigation class 1 to 2 beginning with slope class C rather than D.

Coastal Plain.--Limitations already mentioned on thick surface phases of soils do not apply except that thick surface phases are shifted from irrigation class 1 to irrigation class 2 beginning with slope class C.

Soil Series by Irrigation Classes, Coastal Plain, N.C.

(Applies to general classification considering all crops grown and to most favorable phases of each series)

Irrigation class 1

Productive soils well suited to most crops

Cahaba, Duplin, Faceville, Goldsboro, Kalmia, Kenansville, Magnolia, Marlboro, Nixonton, Norfolk, Orangeburg, Red Bay, Rumford, Ruston, Woodstown.

Irrigation class 2

2a Productive soils, responsive to management but requiring drainage

(Faison and Pasquotank are especially well suited for vegetables) Barclay, Dragston, Dunbar, Faison, Lynchburg, Pasquotank.

2b Coarse subsoils, drouthy, leachy, subject to wind erosion but likely to respond to irrigation (Eustis and Lakeland are leading soils for peach production in the Sandhills).

Blanton, Eustis, Huckabee, Independence, Lakeland, Wando.

2c Fine subsoils, very susceptible to erosion

Caroline (Shubuta), Craven, Flint, Invershiel, Matapeake, Mattapex, Wahee.

2d Moderately coarse to moderately fine subsoils, drainage required but responsive to management and good for vegetables.

Fallsington, Okenee, Pocomoke, Portsmouth, Rains.

Soil series not placed in a subclass.

Hyde, Onslow, Stough, Mixed alluvial land well drained to somewhat poorly drained.

Irrigation class 3

3a Coarse subsoils ranging from somewhat drouthy and leachy to poorly drained and requiring drainage.

Barth, Klej, Scranton

3b Coarse subsoils requiring drainage but difficult to drain. (Very good for leafy vegetables).

Elwell, Rutledge

3c Fine subsoils requiring drainage, generally difficult to drain and till but responsive to management.

Bayboro, Bertie, Bladen, Byars, Coxville, Elkton, Leaf, Lenoir, Othello, Pender.

3d Soils with very serious limitations to farming and rarely farmed

Bibb, Hoffman, Immokalee, Johnston, Leon, Ona, Plummer, St. Johns, St. Lucie, Mixed alluvial land, poorly drained.

Soil series not placed in a subclass

Gilead, Mantachie, Mattamuskeet, Myatt, Vaucluse, Weeksville.

Soil Series by Irrigation Classes, Piedmont, N.C.

(Applies to general classification considering all crops grown and to most favorable phases of each series)

Irrigation class 1

Alamance, Altavista, Appling, Bradley, Bucks, Cecil, Chesterfield, Davidson, Durham, Georgeville, Granville, Hayesville, Herndon, Hiwassee, Lloyd, Madison, Masada, Mayodan, Seneca, Starr, State, Surry, Tirzah, Wadesboro, Wickham, Yadkin.

Irrigation class 2

Augusta, Bermudian, Cataula, Chewacle, Congaree, Creedmoor, Efland, Enon, Grover, Halewood, Helena, Lansdale, Lockhart, Mecklenburg, Mixed alluvial land, Molena, Nason, Pope, Rowland, Tatum, Vance, York.

Irrigation class 3

Bowmansville, Buncombe, Colfax, Elbert, Goldston, Iredell, Lehigh, Louisa, Louisburg, Mantea, Mixed alluvial land, Orange, Penn, Pinkston, Roanoke, Warne, Wehadkee, Wilkes, White Store, Worsham, Zion.

APPENDIX 2. COUNTY ESTIMATES

Table 5.--Crop and pastureland by irrigation classes, North Carolina counties entirely in Coastal Plain

County	General classification irrigation classes-- 1	2	3	Organic soils	Total 1/	Tobacco classification irrigation classes-- 1	2
	Acres	Acres	Acres	Acres		Acres	Acres
Beaufort 2/ 3/	3,661	62,750	83,950	170	150,531	3,661	3,917
Bertie	34,710	44,654	37,150	0	116,515	23,018	46
Bladen 2/	47,602	53,157	11,781	0	112,539	60,340	575
Brunswick	13,541	40,530	14,364	0	68,435	17,932	1,098
Camden	1,876	17,603	10,120	0	29,599	1,519	0
Carteret	84	11,766	5,945	0	17,795	712	0
Chowan	1,343	23,855	23,251	0	48,448	4,017	0
Columbus	61,243	80,945	25,650	0	167,837	84,755	0
Craven	5,847	46,777	31,317	2,676	86,617	15,312	50
Cumberland	24,940	54,520	17,074	0	96,534	39,331	580
Currituck	9,319	22,957	31,574	0	63,850	7,231	0
Dare	0	0	0	0	0	0	0
Duplin 4/	46,134	88,018	26,557	0	160,709	74,714	1,669
Edgecombe	55,902	92,030	20,726	0	168,658	84,471	1,759
Gates	5,398	26,395	16,196	0	47,989	9,650	24
Greene	31,039	55,727	2,861	0	89,627	48,384	0
Hertford	16,177	41,508	12,506	0	70,191	29,149	661
Hoke 2/	8,029	45,028	8,939	0	61,996	22,599	952
Hyde	0	8,680	32,056	905	41,641	0	0
Jones	2,856	21,373	21,650	0	45,879	2,580	829
Lenoir	40,431	71,516	26,263	0	138,210	64,157	1,311
Martin	9,332	73,653	7,951	0	90,935	24,186	0
New Hanover	150	3,392	2,812	0	6,354	150	537
Onslow	11,621	40,425	14,515	0	66,561	18,585	362
Pamlico	52	11,956	29,890	208	42,105	52	0
Pasquotank 4/	2,623	12,949	35,391	0	50,962	1,124	0
Pender	16,521	34,868	9,766	0	61,156	27,201	0
Perquimans 4/	1,797	20,985	50,210	0	72,991	1,533	0
Pitt 3/	33,984	141,537	44,534	0	220,054	33,237	27,262
Robeson 2/	78,406	147,252	31,252	0	256,911	136,131	2,482
Sampson	118,348	130,771	25,509	0	274,628	181,410	4,267
Scotland 2/	16,639	34,240	10,632	0	61,511	33,939	160
Tyrrell	1,794	15,387	16,567	0	33,748	1,794	0
Washington	8,428	23,403	17,185	438	49,454	11,231	0
Wayne	73,752	80,413	14,856	0	169,021	104,997	1,342

1/ Sum of irrigation classes varies slightly from total because of rounding when expanding from sample data.

2/ Estimated errors due to faulty observations in general classification exceed 2 percent of cropland and pasture area; data considered unreliable for general irrigation classes.

3/ Estimated errors due to faulty observations in tobacco classification exceed 2 percent of estimated total cropland and pasture area in tobacco irrigation classes 1 and 2; data considered unreliable for tobacco irrigation classes.

4/ No check was made for errors due to faulty tabulation.

Table 6.--Crop and pastureland by irrigation classes, North Carolina counties partly in Coastal Plain and partly in Piedmont

County	General classification irrigation classes--			Total 1/	Tobacco classification irrigation classes--	
	1	2	3		1	2
	Acres	Acres	Acres	Acres	Acres	Acres
Anson 2/	35,456	52,530	22,114	110,100	31,708	22,592
Halifax	99,184	68,456	9,598	177,237	121,063	7,396
Harnett	70,915	68,000	19,915	158,830	97,436	16,369
Johnston	150,819	112,685	8,331	271,836	201,236	14,000
Lee 3/	13,932	24,183	5,149	43,264	20,828	7,618
Montgomery	9,907	31,859	5,318	47,083	2,408	2,590
Moore	10,173	30,159	16,664	56,996	7,106	2,760
Nash	106,655	48,543	7,582	162,779	125,055	10,356
Northampton	65,147	67,978	7,873	140,997	90,928	2,058
Richmond	16,147	63,547	9,026	88,720	17,327	7,166
Wake	96,130	53,077	15,847	165,053	122,478	10,787
Wilson	71,562	41,081	6,985	119,629	92,127	488

1/ Sum of irrigation classes varies slightly from total because of rounding when expanding from sample data.

2/ No check was made for errors due to faulty tabulation.

3/ Estimated errors due to faulty observations in tobacco classification exceed 2 percent of estimated total cropland and pasture area in tobacco irrigation classes 1 and 2; data considered unreliable for tobacco irrigation classes.

Table 7.—Crop and pastureland by irrigation classes, North Carolina counties entirely in Piedmont

County	General classification irrigation classes— 1	2	3	Mountain soils	Total 1/	Tobacco classification irrigation classes— 1	2
	Acres	Acres	Acres	Acres		Acres	Acres
Alamance	48,311	38,667	25,732	0	112,711	26,235	24,453
Alexander 2/	29,244	17,296	3,548	6,809	56,896	26,974	6,391
Cabarrus 3/ 4/	20,919	55,037	32,352	0	108,308	14,453	10,650
Caswell	33,221	27,788	25,881	0	86,890	30,218	18,827
Catawba 3/ 4/	68,218	53,453	13,037	0	134,708	56,677	25,839
Chatham	16,780	45,061	31,957	0	93,799	5,562	3,111
Cleveland 3/ 4/	58,131	41,364	20,274	0	119,769	62,503	31,852
Davidson 3/ 4/	66,505	48,607	25,431	0	140,542	44,912	16,170
Davie 2/	33,224	33,842	10,670	0	77,735	18,043	2,633
Durham	11,490	11,211	12,606	0	35,307	9,513	1,651
Forsyth	57,971	27,440	14,589	1,884	101,884	47,439	10,918
Franklin	91,098	18,683	19,183	0	128,964	92,189	8,364
Gaston	39,882	24,102	3,916	0	67,900	31,183	4,220
Granville	37,080	47,946	12,946	0	97,972	19,511	16,876
Guilford 3/	65,124	76,679	17,332	0	159,135	66,742	52,968
Iredell	106,978	48,789	27,811	0	183,577	71,658	20,446
Lincoln 3/	67,265	31,236	6,352	0	104,854	61,920	10,188
Mecklenburg	53,055	46,486	24,087	0	123,627	40,008	11,450
Orange 3/	47,495	25,999	8,636	0	82,129	15,646	4,086
Person	32,585	27,282	13,063	0	72,930	19,281	19,570
Randolph	61,036	73,988	27,024	0	162,047	17,798	21,153
Rockingham	64,596	31,843	25,929	0	122,368	64,323	18,060
Rowan	71,868	49,594	14,897	0	136,360	46,024	6,663
Stanly 3/	49,447	49,951	26,145	0	125,543	1,147	1,789
Stokes	45,742	37,250	18,818	0	101,810	41,592	18,142
Union	77,281	83,469	38,786	0	199,537	26,215	19,491
Vance	31,698	18,771	6,818	0	57,288	31,119	7,530
Warren	57,288	18,101	4,236	0	79,625	53,100	9,099
Yadkin 2/	57,812	23,870	9,682	2,637	94,000	52,162	12,444

1/ Sum of irrigation classes varies slightly from total because of rounding when expanding from sample data.

2/ No check was made for errors due to faulty tabulation.

3/ Estimated errors due to faulty observations in general classification exceed 2 percent of cropland and pasture area; data considered unreliable for general irrigation classes.

4/ Estimated errors due to faulty observations in tobacco classification exceed 2 percent of estimated total cropland and pasture area in tobacco irrigation classes 1 and 2; data considered unreliable for tobacco irrigation classes.

Table 8.--Crop and pastureland by irrigation classes, North Carolina counties partly in Piedmont and partly in Mountain (Piedmont portion only)

County	General classification irrigation classes-- 1	2	3	Mountain soils	Total 1/	Tobacco classification irrigation classes-- 1	2
	Acres	Acres	Acres	Acres		Acres	Acres
Burke 2/	26,525	11,854	5,995	7,948	52,323	22,800	3,997
Caldwell	26,721	18,299	7,590	6,082	58,692	25,161	8,422
McDowell 3/	6,777	15,212	828	15,212	38,029	3,012	828
Polk	14,406	7,443	2,449	2,521	26,819	11,693	792
Rutherford	74,078	36,538	13,426	1,536	125,578	63,190	17,968
Surry	60,341	31,018	16,332	3,530	111,222	49,233	19,110
Wilkes	30,314	21,132	19,199	13,356	84,002	19,023	8,655

1/ Sum of irrigation classes varies slightly from total because of rounding when expanding from sample data.

2/ Estimated errors due to faulty observations in tobacco classification exceed 2 percent of estimated total cropland and pasture area in tobacco irrigation classes 1 and 2; data considered unreliable for tobacco irrigation classes.

3/ Estimated errors due to faulty observations in general classification exceed 2 percent of cropland and pasture area; data considered unreliable for general irrigation classes.

APPENDIX 3. MEASUREMENT ERRORS

Measurement errors are defined as errors in recording the acreage falling into each irrigation class in individual sampling units. They may result from:

(1) Errors in mapping the Inventory sample units.

(2) Errors in transferring the original plot data to standard forms for IBM processing. A card was punched for each combination of soil type, slope, erosion, and major land use on each plot.

(3) Errors in sorting and summarizing, for this study, the data from cards pertaining to each sample plot.

Another type of error occurs in adding and expanding sample values. This type of error was not evaluated, and it was assumed that such errors were minimized by careful checking.

Measurement errors may be random or biased. For example, if soils in irrigation class 1 were consistently incorrectly classified as belonging to irrigation class 2, measurement errors would be biased. Because of the large number of soil types and phases included in the Inventory and in each irrigation class, it is unlikely that measurement errors in this study are biased. If measurement errors are random, they will tend to offset each other. However, for the relatively small number of sampling units in a county or even a small aggregation of counties, the estimates could include a considerable error component even if errors are random.

General Considerations in Estimating Measurement Errors

The procedures used to evaluate measurement error will depend on how the error is believed to be distributed among sampling units. Three situations are possible.

(1) Errors are distributed over all sampling units.

(2) Errors are concentrated on sampling units containing certain types of land and are negligible on other sampling units.

(3) Errors are more likely to occur on certain types of sampling units but are still significant on all units.

Situations 2 and 3 could occur in combination. This is true for the North Carolina Study, where only the acres of cropland and pasture were estimated for each of several irrigation classes. It is most unlikely that woodland was mistakenly classified as cropland or pasture in a given irrigation class; therefore measurement error on woodland may be assumed to be negligible.

At the same time it is also more likely that errors in recording acreage in a given irrigation class occurred on sampling units having some acreage in that class. This is true because it is more likely that mistakes were made on

sampling units where a number of soils appear to fall in that irrigation class than on sampling units where the soils clearly do not fall in this class.

For aggregations, the procedures for estimating measurement error will also depend on whether interest centers on the total measurement error or whether information is also desired on measurement errors in individual counties.

In all cases, the Inventory sample of a county may be regarded as the universe for error estimation. A random subsample can then be drawn from the Inventory sampling units and expanded to the Inventory sample. The estimated error in the entire Inventory sample can then, in turn, be expanded to the county universe by use of the standard expansion factor.

Error Estimation for Coastal Plain and Piedmont

The primary objective was to estimate measurement error for the entire Coastal Plain and entire Piedmont. A secondary objective was to ascertain whether measurement errors were important for individual counties. For the primary objective the number of Inventory sampling units checked for error should be in proportion to the estimated area of cropland and pasture in each county, except for heavier than proportionate sampling for counties which are believed to have great variability in measurement error. However, since a minimal information on sampling error was desired for each county, 4 sampling units were selected randomly per county.

Measurement error was assumed to be limited to only those portions of the sample units area having cropland and pasture and to be zero for sample units having no open land. Therefore, Inventory units with no cropland and pasture were not checked for measurement error. Only the cropland and pasture portions of the plots subsampled were examined.

Measurement associated with a given irrigation class is more likely on sampling units showing some land in that irrigation class. Therefore, a more precise estimate would have been obtained by (1) dividing the Inventory sample into sampling units showing some land in a given irrigation class and those showing no land in that class, and (2) sampling the former at a heavier rate. However, it was not feasible to draw a different subsample for each of the 3 general and 2 tobacco subclasses that were checked for error.

The procedure may be illustrated for Greene County. The 4 sampling units drawn at random for checking had 363 acres of open land. Of these, 1 acre in irrigation class 1 was found to be mistakenly placed in irrigation class 2 both in the general and the tobacco classification. The total open land in the Inventory sample for the county was 3,979 acres.

The measurement error in the Inventory sample for Greene County was estimated at $3{,}979 \div 363 \times 1 = 10.961$. This error was then multiplied by the county expansion factor of 22.525, giving an estimated measurement error of 247 acres for irrigation classes 1 and 2 both in the general and the tobacco classification.

The check was carried out by comparing photostats of the original tally sheets against IBM summary tabulations for each plot subsampled for measurement error. No check could be made of the original soil mapping. This check covered errors in transfer of the original data to IBM cards as well as errors associated with coding and tabulation for this study. Some discrepancies recorded as measurement errors may in fact not be errors, but be due to an editing of the original plot data at the time they were transferred to standard forms for IBM processing.

For Bladen, Lee, and Vance Counties, the original tally sheets were unavailable. Therefore, a check of the IBM results had to be made against the standardized tally sheets to which the original tallies were transferred for machine processing.

Because only 4 sampling units were examined per county, probability statements cannot be prepared for the type of estimating procedures used. As a working rule, whenever the estimated acres misclassified under the general classification exceeded 2 percent of the total cropland and pasture area as determined from the Inventory, county estimates were considered unreliable for the general classification. Whenever the estimated acres misclassified under tobacco classes 1 and 2 exceeded 2 percent of the estimated total cropland and pasture area in those 2 classes, the county results were considered unreliable for the tobacco classification.

Estimates of measurement errors for the Coastal Plain and Piedmont are summarized in table 9. The acres misclassified in each irrigation class are given as a percent of total acres estimated for that class on the assumption that the same prevalence of error exists in the 7 counties that could not be checked for measurement error. Except for tobacco irrigation class 2 in the Coastal Plain, a minor class (table 2), measurement errors appear to be at a low level.

Table 9.--Estimated measurement errors, Coastal Plain and Piedmont, N.C.

Irrigation class	Estimated measurement error	
	Coastal Plain	Piedmont
	Percent 1/	Percent 1/
General classification		
1	0.3	1.9
2	1.1	1.3
3	3.1	1.9
Tobacco classification		
1	1.0	3.2
2	17.5	0.3

1/ Measurement error for each irrigation class expressed as percent of total estimated acres in the same class.

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No separate evaluation of measurement errors was undertaken for the Neuse River Basin, but measurement error appears to be minor in that area. The measurement error subsample for the Coastal Plain and Piedmont included 2,018 acres of cropland and pasture in the Neuse River Basin. Of this area only 5 acres in the general classification and 4 acres in the tobacco classification were found to be misclassified.